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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

02027409.8

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

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ALLEMAGNE

Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Filter

In Anspruch genommene Priorität(en) / Priority(ies) claimed /Priorité(s) revendiquée(s)
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H04L27/26

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Contents

1 Abbreviations

f_{IF}	IF frequency
f_{bin}	frequency distance between neighbor subcarriers
$H_{...}(f)$	filter transfer function
i	time index of the sampled sequence
k	channel index of occupied subcarriers $k=[-26,26]$
$T_s = 1/f_s$	sample period and frequency respectively

2 FSP Processing for the IEEE802.11a application

The first application note [1] describes the W-LAN signal processing of th FSQ. The available bandwidth of the FSQ is 27 MHz and therefore sufficient to measure the IEEE802.11a signal with a bandwidth of 16.4 MHz.

In this application note the W-LAN application is discussed for the cheaper FSP. The main problem is the smaller FSP analyzer bandwidth of 8 MHz which only covers half of the OFDM signal bandwidth. The main idea is to analyze the spectrally cut measurement signal with carefully designed filters. First simulations have shown that following properties can b expected:

- About 20 of the 52 subcarriers can be analyzed within a measurement.
- The position of the analyzing window can be selected by the operator, e.g. to analyze the left, the middle or the right subcarriers.
- Also symbolwise tracking of timing, phase and gain is supported.

In **figure 1** the diagram of the interesting blocks is shown. The description starts with the IF signal $r_{IF}(t)$ at the IF frequency f_{IF} = 21.4 MHz. For simplification the IF signal is not yet bandlimited. The FSP bandwidth of 8 MHz is modelled by the subsequent IF filter with the frequency transfer function $H_{IF}(f)$. The schematic spectrum $R_{IF}(f)$ of the input signal is shown in the lower part of the figure. It can be seen that the middle of the

OFDM spectrum (at subcarrier $k=0$) is shifted from the IF frequency f_{IF} by the user definable frequency offset f_{offset}. By varying f_{offset} the position of the analyzing window can be changed. If for example the frequ ncy offset is set to $f_{offset}=0$, the analyzing window is set in the middle of the OFDM spectrum. Furthermore the schematic transfer function $H_{IF}(f)$ is shown in the lower figure. The passband bandwidth is 8 MHz and symmetric to the IF frequency. The subcarriers in the undistorted passband will be analyzed by the application.

The main task of the IF filter is to avoid aliasing effects in the 8 MHz analyzing window by the subsequent sampling process of the Analog to Digital Converter (ADC). The sampling rate of the ADC is $f_{s1}=32$ MHz.

Next the sampled IF sequence is multiplied with the sequence $e^{-j\omega_{IF}\cdot iT_{s1}}$, whereby the sampling period is defined by $T_{s1}=1/f_{s1}$. This complex multiplication effects a spectral shift from the IF frequency f_{IF} to baseband.

The following lowpass filter with the transfer function $H_{LP}(f)$ also possesses the passband bandwidth of 8 MHz (see schematic plot) and fulfils two tasks:

1. Suppression of the mirror at $f=-2f_{IF}$ caused by the spectral shift.
2. The lowpass filter must avoid aliasing effects in the 8 MHz analyzing window caused by the subsequent resampling process. As the resampling process reduces the sampling rate, the transition band must be steeper compared to the IF filter.

Next the sampling must be changed to the Nyquist rate. This is performed by a digital resampler. The output sequence is generated at the desired Nyquist rate of $f_{s2}=20$ MHz.

Afterwards the resampled sequence is multiplied with the sequ nce $e^{-j\omega_{offset}\cdot iT_{s2}}$. This operation generates a further spectral shift by the frequency f_{offset}.[1] The resulting output sequence is described by $r(i)$.

The schematic spectrum $R(f)$ is shown in the lower part of the figure. It is transparent that $r(i)$ is the OFDM signal in baseband position, i.e. the channel $k=0$ is at the frequency $f=0$. Furthermore the subcarriers within the analyzing window of 8 MHz are not distorted. The position of the

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[1] This spectral shift can not be integrated in the first downconversion, because the resampling process requires a lowpass input sequence.

analyzing window can be chosen by the correspondent frequency offset f_{offset}.

Afterwards the sequence $r(i)$ enters into the W-LAN application which is equivalent to the FSQ implementation. A more detailed description of this application can be found in the first application note [1] (see signal processing in the lower part of figure 1).

Finally the influence of the 8 MHz bandpass filtering should be discussed: The equivalent impulse response length of the bandpass filter is given by

$$T = 1/8\,\mathrm{MHz} = 125\,\mathrm{ns}\,.$$

This length corresponds to 2.5 Nyquist periods of the 16 sample guard period. From this point of view, only small inter symbol interference (ISI) should be expected. First simulations have confirmed this statement. But care must be taken in the filter design in order to minimise any ISI effects.

How many subcarriers can be analyzed in a measurement? The maximum number of subcarriers within the transmission band of 8 MHz is

$$nof_{Subcarrier} = \frac{f_{pass}}{f_{bin}} = \frac{8\,\mathrm{MHz}}{312.5\,kHz} \approx 25\,.$$

From a more conservative view about 20 subcarriers can be used for th measurement.

It should be noticed that even this bandlimited measurement supports symbolwise tracking. This is possible because there are always 2 pilot subcarriers within the 8 MHz analyzing window. The pilots are used for symbolwise tracking (optional phase and/or timing and/or gain). The smaller number of used pilots (2 instead of 4) leads to a higher estimation error of the synchronization parameters and consequently to an increase of the EVM compared to a measurement with no limitation of the bandwidth. The statistical increase can be calculated however.

Furthermore the simulations have shown that the preambl synchronisation also works well in the case of the bandlimited OFDM signal and is robust for low signal to noise ratios.

Claim

1. A filter for avoiding aliasing effects in the analysing window wherein the sampled sequence is multiplied with the sequence $e^{-jw_{IF} \cdot iT_{s1}}$ effecting a spectral shift to the baseband.

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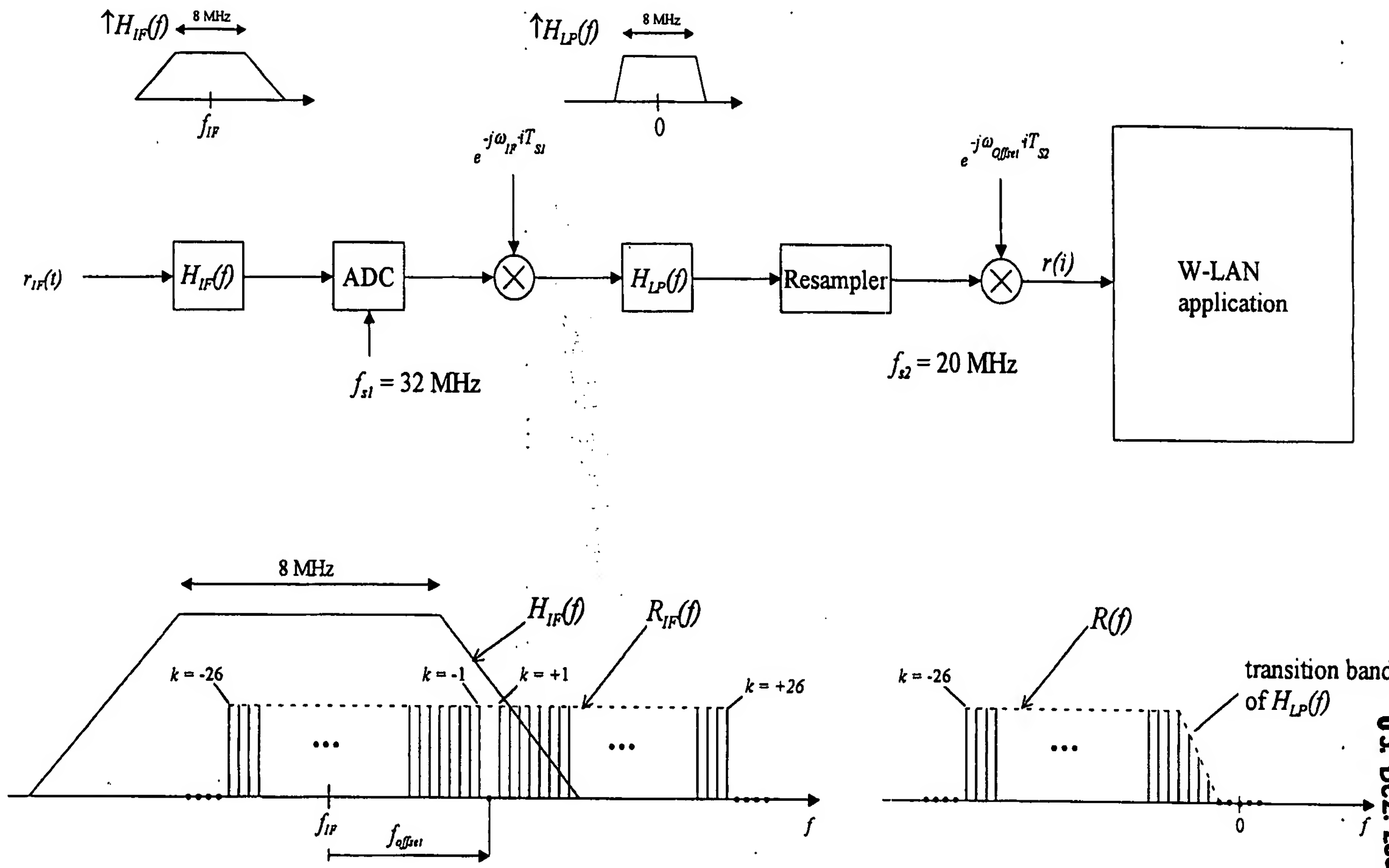

Figure 1: Signal processing of W-LAN application in FSP

Fig. 1

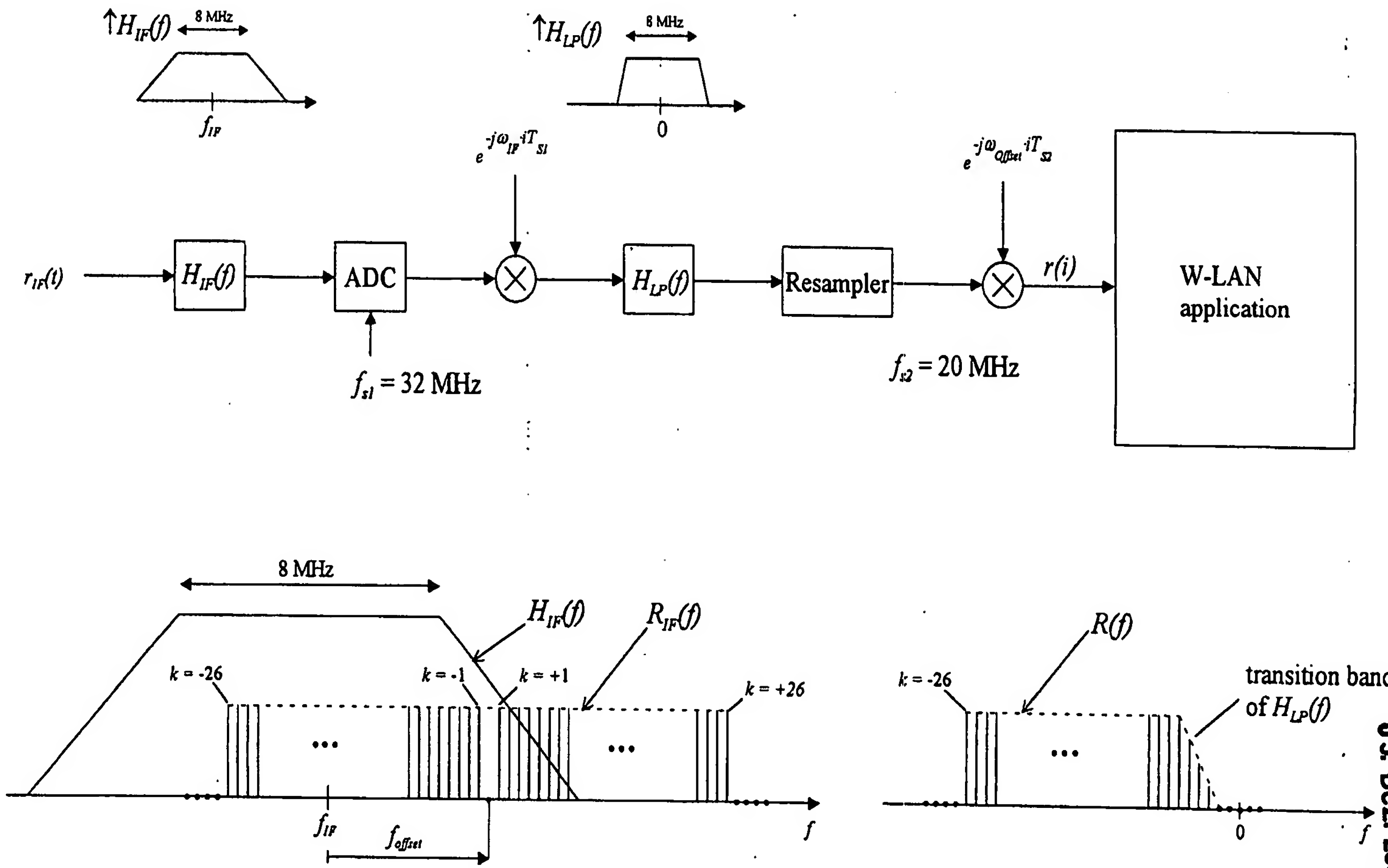

Figure 1: Signal processing of W-LAN application in FSP

Fig. 1

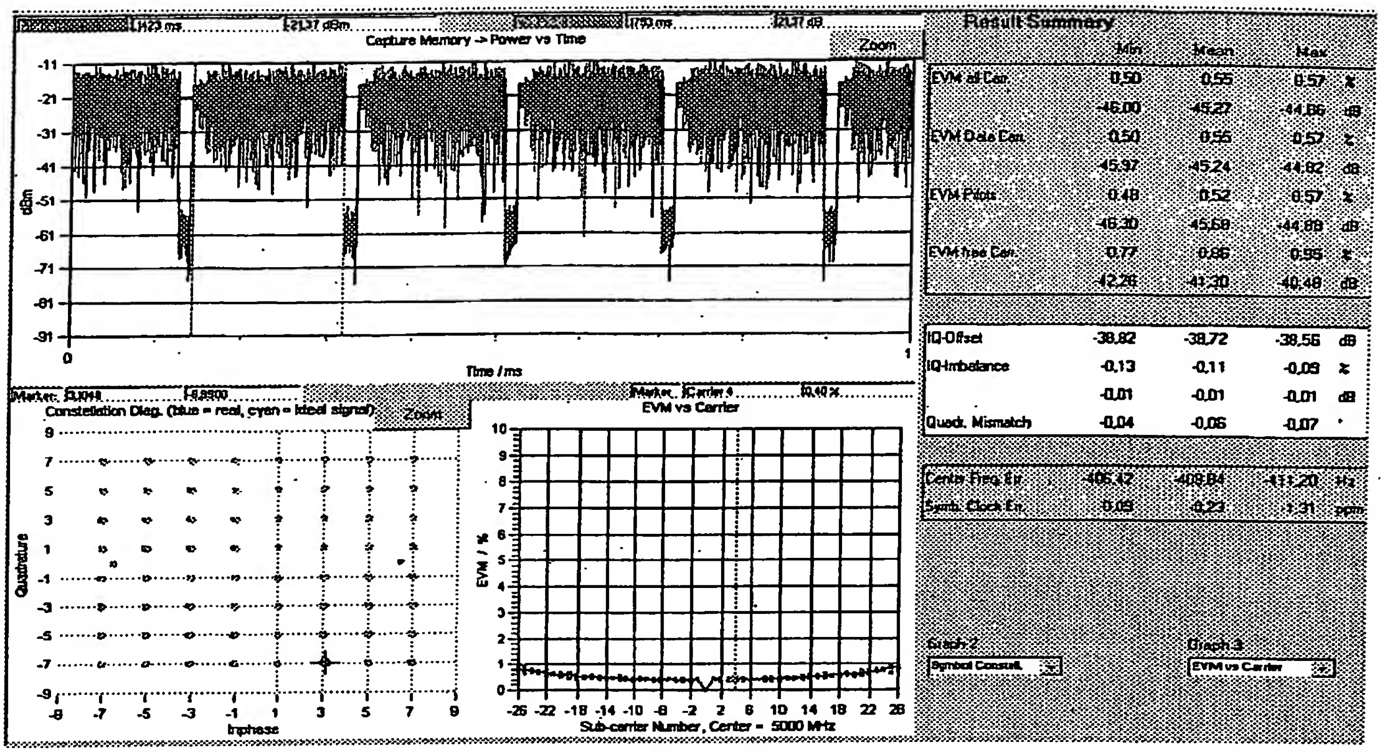
Capture Memory -> Power vs Time
Zoom
Result Summary
Min
Mean
Max
dBm
Time / ms
Constellation Diag. (blue = real, cyan = ideal signal)
EVM vs Carrier
Quadrature
Inphase
EVM / %
Sub-carrier Number, Center = 5000 MHz
IQ-Offset
IQ-Imbalance
Quadr. Mismatch
Graph 2
Graph 3
EVM vs Carrier

Fig. 2